Indicator: Lake and Stream Acidity (041)

Acid deposition can have serious effects on aquatic ecosystems. For example, aquatic organisms in acidified waters can develop calcium deficiencies that weaken bones and exoskeletons and cause eggs to be weak or brittle; acidified waters can impair the ability of fish gills to take in oxygen from water; and increasing amounts of acid in surface water can change the mobility of certain trace metals (e.g., aluminum, cadmium, manganese, iron, arsenic, mercury), which in turn can place fish and other species sensitive to these metals at risk (Acid Deposition: State of Science and Technology, Volume II, Aquatic Processes and Effects). The Indicator "Acid Deposition" explains the factors that contribute to acid deposition and describes how acid deposition patterns have changed over the last 15 years.

The capacity of a water body to "resist" acidification depends on the ability of the water and watershed soils to neutralize the acid deposition it receives. The best measure of this ability is acid neutralizing capacity (ANC), which characterizes the amount of dissolved compounds that will counteract acidity. ANC depends largely on the surrounding watershed's physical characteristics, such as geology, soils, and size. Surface water with an ANC greater than 200 micro equivalents per liter (µeq/L) is usually considered non-acidic; surface water with an ANC less than 50 µeq/L is considered highly sensitive to acidification (is often seasonally acidic); and surface water with an ANC less than 0 µeq/L is considered chronically acidic, meaning the watershed no longer has the capacity to neutralize further acid deposition (EPA 2003).

This indicator is derived from ANC measurements on probability survey samples representing 5, 617 lakes and 72,000 stream miles in the five geographic regions shown in Figure 041-1 as part of the TIME (Temporally Integrated Monitoring of Ecosystems) and on 120 additional acid-sensitive lakes and 78 acid-sensitive streams in the LTM (Long-Term Monitoring) project, for which data were available between 1990 and 2000 (EPA 2003, pg 5). The lakes sampled include only those in areas potentially sensitive to acidification with areas greater than 4 hectares. Smaller lakes generally are not used in this type of assessment because they are more likely to be acidic due to natural causes, although acid deposition can cause them to become further acidified.

What the Data Show

Between 1990 and 2000, ANC in lakes in the Adirondacks and the Upper Midwest (northeastern Minnesota, northern Wisconsin, and northern Michigan) and in streams in the Northern Appalachians (southern New York, west-central Pennsylvania, and eastern West Virginia) has increased to a degree where approximately 30% of the water bodies labeled "chronically acidic in 1990 were no longer classified as such in 2000 (Figure 041-1). This increase suggests that surface waters in these areas are beginning to recover from acidification. However, acidic surface waters are still found in these regions.

The ANC in lakes in New England and streams in the Ridge/Blue Ridge region (east-central Pennsylvania, western Maryland, and western Virginia) have not risen from their 1990 levels. Therefore, all of the water bodies classified as "chronically acidic" in these regions in 1990 still kept that label in 2000.

The trend of increasing ANC in the Adirondacks, the Upper Midwest, and the Northern Appalachian region during the 1990s corresponds with a decrease in acid deposition in each of these regions (see Indicator "Acid Deposition") and reduced air emissions of the main precursors to acid deposition (sulfur dioxide (see Indicator "SO2 Emissions") and nitrogen oxides (see Indicator "NOx Emissions")) during the same time period.

Indicator Limitations

- ANC sampling is limited to five regions, concentrated in the Northeast. There is no coverage in the Southeast, West, or much of the Midwest. These regions were chosen for sampling because previous research has shown that they are among the most sensitive to acid deposition due to the soils and other watershed characteristics. In addition, as Indicator “Acid Deposition” shows, many of these regions receive the highest rates of acid deposition in the U.S. For these two reasons the waters sampled are likely to be at the greatest risk of becoming acidified.
- Interpreting trends for this indicator is complicated because multiple factors contribute to changes in ANC levels. For example, in areas where watershed soil characteristics are changing (e.g., decreases in concentrations of base cations in the soil), even dramatic reductions in acid deposition will not necessarily result in large rebounds in ANC levels.

Data Sources

Stoddard, J. L., J. S. Kahl, F. A. Deviney, D. R. DeWalle, C. T. Driscoll, A. T. Herlihy, J. H. Kellogg, P. S. Murdoch, J. R. Webb, and K. E. Webster. *Response of surface water chemistry to the Clean Air Act Amendments of 1990.* 2003. EPA/620/R-03/001, U.S. Environmental Protection Agency, Washington, DC.

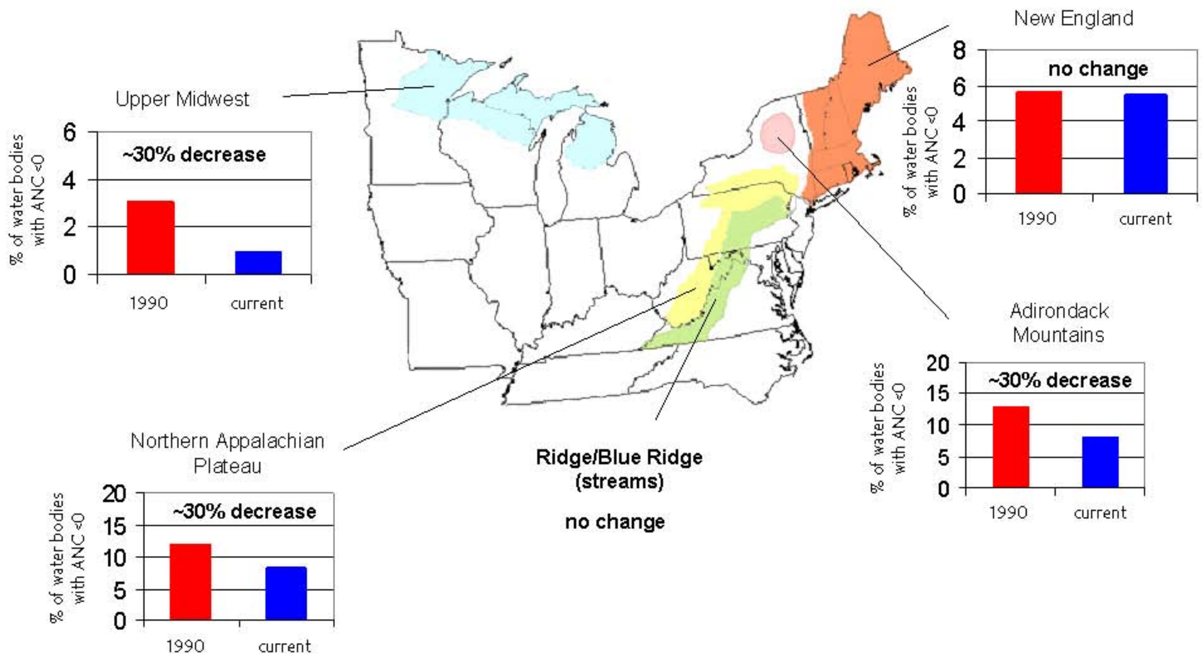
References

National Acid Precipitation Assessment Program. 1991.Acid Deposition: State of Science and Technology, Volume II, Aquatic Processes and Effects, Washington, DC: National Acid Precipitation Assessment Program,

U.S. Environmental Protection Agency. 2003 Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990, EPA 620-R-03-001. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, January

Graphics

Figure 041-1: Change in Chronic Acidity in Lakes and Streams as Measured by Acid Neutralizing Capacity (ANC)



R.O.E. Indicator QA/QC

Data Set Name: LAKE & STREAM ACIDITY
Indicator Number: 041 (89069)
Data Set Source:
Data Collection Date: 1990-2000
Data Collection Frequency: See referenced report.
Data Set Description: Lake & Stream Acidity
Primary ROE Question: What are the trends in extent and condition of fresh surface waters in the United States?

Question/Response

T1Q1 Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Yes, Acid Neutralizing Capacity has been used in every major assessment of surface water acidification for the past 20 years. It is a direct measurement of water's ability to neutralize acid, and is therefore a direct indicator of a lake or stream's ability to neutralize acid rain. The best reference for the method is Section 5 of: U.S.

Environmental Protection Agency. 1987. Handbook of Methods for Acid Deposition Studies: Laboratory Analysis for Surface Water Chemistry. EPA 600/4-87/026, U.S. Environmental Protection Agency, Washington, D.C. Further references can be found in the Quality Assurance plans for the TIME and LTM projects: Morrison, M. 1991. Quality Assurance Plan for the Long-Term Monitoring Project. Pages 1.1-B.1 in U.S. Environmental Protection Agency, Data User's Guide to the United States Environmental Protection Agency's Long-Term Monitoring Project: Quality Assurance Plan and Data Dictionary. U.S. Environmental Protection Agency, Corvallis, OR. Newell, A. D., C. F. Powers, and S. J. Christie. 1987. Analysis of Data from Long-term Monitoring of Lakes. U.S. Environmental Protection Agency, Corvallis, OR. Peck, D. V. 1992. Environmental Monitoring and Assessment Program: Integrated Quality Assurance Project Plan for the Surface Waters Resource Group. EPA/600/X-91/080, U.S. Environmental Protection Agency.

T1Q2 Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

Yes, The sampling/monitoring design is based on sound scientific principles. This sampling/monitoring plan has been used in a number of peer reviewed publications. Some examples of these peer-reviewed publications are: Kahl, J. S., J. L. Stoddard, R. Haueber, S. G. Paulsen, R. Birnbaum, F. A. Deviney, J. R. Webb, D. R. DeWalle, W. Sharpe, C. T. Driscoll, A. T. Herlihy, J. H. Kellogg, P. S. Murdoch, K. Roy, K. E. Webster, and N. S. Urquhart. 2004. Have U.S. surface waters responded to the Clean Air Act Amendments. Environmental Science and Technology 38:485A-490A. Skjelkvåle, B. L., J. L. Stoddard, and T. Andersen. 2001. Trends in surface water acidification in Europe and North America (1989-1998). Water Air and Soil Pollution 130:787-792. Stoddard, J. L., D. S. Jeffries, A. Lükewille, T. A. Clair, P. J. Dillon, C. T. Driscoll, M. Forsius, M. Johannessen, J. S. Kahl, J. H. Kellogg, A. Kemp, J. Mannio, D. Monteith, P. S. Murdoch, S. Patrick, A. Rebsdorf, B. L. Skjelkvåle, M. Stainton, T. Traaen, H. van Dam, K. E. Webster, J. Wieting, and A. Wilander. 1999. Regional trends in aquatic recovery from acidification in North America and Europe. Nature 401:575-578. Stoddard, J. L., J. S. Kahl, F. A. Deviney, D. R. DeWalle, C. T. Driscoll, A. T. Herlihy, J. H. Kellogg, P. S. Murdoch, J. R. Webb, and K. E. Webster. 2003. Response of surface water chemistry to the Clean Air Act Amendments of 1990. EPA/620/R-03/001, U.S. Environmental Protection Agency, Corvallis, Oregon.

T1Q3 Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

Not applicable

T2Q1 To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

T2Q2 To what extent does the sampling design represent sensitive populations or ecosystems?

The TIME (Temporally Integrated Monitoring of Ecosystems) and LTM (Long-Term Monitoring) projects are focused on surface waters sensitive to acidification. Some references documenting this: Stoddard, J. L., C. T. Driscoll, S. Kahl, and J. Kellogg. 1998. Can site-specific trends be extrapolated to a region? An acidification example for the Northeast. Ecological Applications 8:288-299. Stoddard, J. L., A. D. Newell, N. S. Urquhart, and D. Kugler. 1996. The TIME project design: II. Detection of regional acidification trends. Water Resources Research 32:2529-2538. Young, T. C., and J. L. Stoddard. 1996. The TIME project design: I. Classification of Northeast lakes using a combination of geographic, hydrogeochemical, and multivariate techniques. Water Resources Research 32:2517-2528.

T2Q3 Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

Yes. As chemically defined, an ANC value of zero is the threshold between acidic and non-acidic water. It is the ideal cut-point for use in assessments of acidification. This threshold is consitently used across the spatial and temporal extent of the data set.

T3Q1 What documentation clearly and completely describes the underlying sampling and analytical procedures used?

Stoddard, J. L., J. S. Kahl, F. A. Deviney, D. R. DeWalle, C. T. Driscoll, A. T. Herlihy, J. H. Kellogg, P. S. Murdoch, J. R. Webb, and K. E. Webster. 2003. Response of surface water chemistry to the Clean Air Act Amendments of 1990. EPA/620/R-03/001, U.S. Environmental Protection Agency, Corvallis, Oregon. Additional references can be found in the response to question T1Q1

T3Q2 Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

Yes, The data are collected through a series of cooperative agreements with cooperating Universities and Agencies. There exists an informal confidentiality agreement which states that data less than two years old will only be used for official reports, and will not be made publicly available. For the purposes of the ROE, all verified and validated data are accessible.

T3Q3 Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Yes

T3Q4 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

QA procedures can be found in the following documents: Morrison, M. 1991. Quality Assurance Plan for the Long-Term Monitoring Project. Pages 1.1-B.1 in U.S. Environmental Protection Agency, Data User's Guide to the United States Environmental Protection Agency's Long-Term Monitoring Project: Quality Assurance Plan and Data Dictionary. U.S. Environmental Protection Agency, Corvallis, OR. Newell, A. D., C. F. Powers, and S. J. Christie. 1987. Analysis of Data from Long-term Monitoring of Lakes. U.S. Environmental Protection Agency, Corvallis, OR. Peck, D. V. 1992. Environmental Monitoring and Assessment Program: Integrated Quality Assurance Project Plan for the Surface Waters Resource Group. EPA/600/X-91/080, U.S. Environmental Protection Agency.

T4Q1 Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

Yes, The TIME project uses a statistical survey method to select sites for sampling, and its results can be extrapolated to target populations of streams and lakes. See examples in: Stoddard, J. L., J. S. Kahl, F. A. Deviney, D. R. DeWalle, C. T. Driscoll, A. T. Herlihy, J. H. Kellogg, P. S. Murdoch, J. R. Webb, and K. E. Webster. 2003. Response of surface water chemistry to the Clean Air Act Amendments of 1990. EPA/620/R-03/001, U.S. Environmental Protection Agency, Corvallis, Oregon.

T4Q2 Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

Yes, See data on variability in: Stoddard, J. L., A. D. Newell, N. S. Urquhart, and D. Kugler. 1996. The TIME project design: II. Detection of regional acidification trends. Water Resources Research 32:2529-2538.

T4Q3 Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

No, a description of the uncertainty and variability and it's impacts on our ability to detect trends can be found in Stoddard, J. L., A. D. Newell, N. S. Urquhart, and D. Kugler. 1996. The TIME project design: II. Detection of regional acidification trends. Water Resources Research 32:2529-2538.

T4Q4 Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

No, although the target population does not include all geographic areas that have lakes and streams that are sensitive to acid deposition.